

CHAPTER 8

OVERCURRENT PROTECTIVE AND SWITCHING DEVICES

Section I-CONSIDERATIONS

8-1. Circuit interrupting devices.

This chapter describes circuit interrupting devices that can make (close), break (open), or modify the connections of an electrical system either under normal or (as a protective device) abnormal conditions or both. Included are fuses, switches, circuit breakers, circuit switchers, and reclosers.

a. Purpose of devices. Each of the devices provides one or more of the functions listed below:

- (1) Switching-opening and closing of energized or de-energized circuits.
- (2) Overcurrent protection-circuit interruption under excessive or fault current conditions.
- (3) Automatic reclosing after overcurrent opening.

b. Devices may be classified by their insulating medium, such as:

- (1) Air
- (2) Vacuum
- (3) Sulfur hexafluoride (SF₆)
- (4) Oil
- (5) A combination of the above

c. Devices may be operated in the following manner:

- (1) Internal action
- (2) Manually operated external action
- (3) Automatically operated external action

8-2. Location of protective and switching devices.

These devices may be self-contained units, or installed in assemblies with other devices. The units or assemblies may be installed indoors or outdoors in enclosures suitable for protected or exposed installations respectively. Devices will normally be insulated for medium-voltage and high-voltage levels, except for secondary switchgear.

8-3. Protective and switching device instruction manuals.

Neither adjustments nor replacements of parts of switching apparatus should be attempted without first consulting the manufacturer's instruction manuals. If the manuals furnished with switching apparatus, especially any power-operated switching devices and any circuit breakers, are unavailable, every effort should be made to obtain copies from the nearest office of the applicable manufacturer.

8-4. Protective and switching device records.

Service operating records should be maintained on all switching apparatus. These records should include a history of all ampere ratings or settings, operations, and maintenance and inspections.

Section II-FUSES

8-5. Fuse usage.

Fuses provide relatively inexpensive protection by opening an electric line when a short circuit or overload occurs on the load side of the fuse. Always remember that a fuse is a single-phase device.

a. Construction. A fuse is designed to be an intentionally-weakened link in an electric circuit and to be the first point of failure.

(1) *Fuse link.* A fuse link uses a metal such as silver, tin, lead, copper or any alloy, which will melt when a predetermined current is maintained for a predetermined time period. The fuse's melting current (rating) is selected to permit severing the circuit before the same current could damage the electrical system.

(2) *Fuse tube.* A fuse tube is provided to prevent damage from the melting fuse link, which otherwise might start a fire from possible flying metal, and to aid in quenching the arc developed by sever-

ing the circuit. The fuse tube also provides the means of making contact with the rest of the electrical circuit.

b. Types. Only medium- and high-voltage fuses are covered in this manual. Most fuses commonly used on facility electrical distribution systems are distribution fuse cutouts and power fuses. The applicable industry standards differentiate between the two categories on the basis of their dielectric withstand or basic insulation level (BIL) either at distribution or power levels respectively. Fuse selections are also influenced by their installation application.

(1) *Distribution fuse cutouts.* A distribution cutout provides a mounting for the fuse element. Some cutouts have arc chutes designed for load-break operation. Fuse cutouts are not usually provided for switching circuits, but for protection of overhead equipment and sectionalizing of lines. Cutouts normally use an expulsion fuse, wherein

the arc produces a gas. A blown fuse may be indicated by dropping of the fuse, dropping of the door on an enclosed cutout, or by loss of an expendable vent cap, which yields to relieve the internal pressure.

(2) *Power fuses.* Power fuses can be fixed or dropout expulsion noncurrent-limiting type (solid material boric acid) or nonexpulsion current-limiting type (silver element with high-purity silica sand). The reduced explosive emissions of boric acid fuses permit their use in enclosures.

(3) *Selection by location.* The selection by location is based on installing fuses which liberate gases (that is, some expulsion fuses) in outside locations, where protective enclosures such as switchgear are not required. Current-limiting fuses are expensive as compared to expulsion fuses.

(a) *For use within confined spaces.* Power fuses of the nonexpulsion current-limiting (silver-sand) type and expulsion solid material (boric acid) type comprise the majority of fuses suitable for application within buildings, vaults, or enclosures.

(b) *For outdoor applications.* Distribution fuse cutouts have a mechanical construction adapted to pole or crossarm mounting. Power fuses can also be used.

(4) *Other types of medium-voltage fuses.* Other types of fuses used on medium-voltage lines are current-limiting protectors, electronic fuses, liquid-type power fuses, and oil fuse cutouts.

(a) *High-current or high-speed interruption.* A current-limiting protector can carry high currents and yet limit let-through short circuit currents. Electronic fuses provide high-speed interruption of fault currents. Both are more expensive than distribution fuse cutouts or power fuses, and their use is limited for most facility applications.

(b) *Liquid fuses.* Liquid-type noncurrent-limiting power fuses have lower continuous and interrupting current capacities than other fuses. Liquid-type fuses have been used for wood-pole mounted applications in high-risk fire areas. The arc-quenching liquid is a petroleum product, which is not considered environmentally advisable so they should not be replaced. A new fuse holder will also be required, since the liquid-type fuse holder will not accept other types of fuses.

(c) *Oil fuse cutouts.* Oil fuse cutouts are not used as frequently as in the past, because of both environmental concerns and their lower interrupting duty.

8-6. Fuse operating safety considerations.

When operating fused devices, the following considerations apply.

a. *Nonload-break devices.* A nonload-break fused device energizing a circuit following fuse replacement should not be reopened unless the fuse has again blown or the circuit has been de-energized.

b. *Load-break devices.* A load-break fused device energizing a circuit following fuse replacement should not be reopened immediately. The time delay before reopening must allow the fuse to blow if there is an existing fault current beyond the load-break rating of the device. For fuse links of more than 100 amperes, this time delay could be as long as 10 minutes.

c. *Open fuse holder.* Outdoor fuses should be closed as soon as possible. Fuses left hanging for extended periods can undergo water damage and warpage, making reclosing of an energized circuit dangerous.

8-7. Fuse replacement.

Make certain that fuses, whether new or replacements, are of the proper type and rating. Never replace one type of fuse arbitrarily with a different type of fuse of the same physical size, or with a fuse having a different current rating, without specific engineering direction. Noncurrent-limiting fuses should not be used to replace current-limiting fuses.

a. *Spare fuse units and replaceable parts.* Mark and store parts for re-energizing, after locating and correcting the situation that caused the fuse to blow. A potential hazard may exist, if the circuit is re-energized with the fault condition still present.

(1) *Marking of spare fuses and parts.* Spare fuse units should be suitably marked, coded, or indexed to show the mounting, circuits, or equipment with which they are to be used; especially if several types and ratings are used in a given location. This minimizes the possibility of improper application.

(2) *Storing spare fuse units and parts.* Store spare fuse units and replaceable parts of fuse units so they will not be damaged, and will be readily available when needed.

b. *Fuses subject to partial melting or deterioration.* Fuses can be partially melted or damaged by fault currents of insufficient magnitude and melting time to cause complete melting. Observe the following precautions:

(1) In two- or three-phase applications, replace fuses in, all phases, when fuses in one or more phases are blown.

(2) In applications where fuses are used in series with other fuses or interrupting devices in the same phase, in such a manner that their melting or clearing curves, or both, cross one another, it is advisable to consider that the blowing of one makes the other unsuitable for continued service.

c. Replacing fuses on capacitor installations. Fuses used on capacitors should not be removed or replaced by hand, unless due precautions are taken beforehand to discharge and ground the capacitors in accordance with chapter 13, section II. The entire capacitor bank should be disconnected and grounded while replacing the fuses, unless the fuse link or its mounting, or both, can be removed safely and completely from the circuit using hot line tools.

d. Replacing of vented fuses. Vented fuses being replaced within this venting area should be deenergized during replacement. Vented fuses, operable from outside their vented area, may be replaced without deenergizing the circuit, but the use of hearing protectors is recommended.

e. Replacing of current-limiting nonvented type. Careless handling of these inherently fragile fuses may result in damage. When damage is suspected, the fuse should not be used.

f. Expendable cap cutouts. Do not install a nonexpendable cap on an expendable cap cutout because of the resulting reduction of the expendable cap cutout's interrupting capability.

8-8. Fuse maintenance.

The frequency of fuse inspection and maintenance must be determined based on the environmental conditions at the fuse location. Periodically inspect fuses which have not blown after a long period of time to guard against oxidation. Contact clips and ferrules (fuse terminals) can be covered with a special noncorrosive conductive lubricant. Before fuses are removed or installed, the fuse holders must be disconnected from the power source.

a. Fuses in general. The following procedures should be standard for all fuses:

(1) Inspect the fuse unit and renewable element (if the fuse is a renewable type) for corrosion, tracking, and dirt. Replace those units that indicate deteriorated condition.

(2) Inspect fuse holder insulators for dirt, dust, salt deposit, and the like, which can cause flashover. Also look for cracks or burn marks on insulators.

(3) For vented expulsion-type fuses, inspect the seal on the expulsion chamber to ensure that no moisture has entered the interrupting chamber of the fuse.

(4) Check for any missing or damaged hardware, such as nuts, bolts, washers, and pins.

(5) Clean and polish contact surfaces of clips and ferrules that are corroded or oxidized.

(6) Tighten all loose connections and check to see if the fuse clips exert sufficient pressure to maintain good contact.

(7) Fuses that show signs of deterioration, such as loose connections, discoloration, or damaged casing should normally be replaced.

b. Periodic inspection of fuse links in distribution cutouts. These fuse links may require periodic inspections, since corrosion of the lower terminal of the fuse link (generally a flexible cable) at the lower open-end of the fuse holder may cause breakage or melting at this point, rather than in the current-responsive element. Link-break cutouts are particularly susceptible since their link-break mechanisms impose a mechanical strain on fuses.

c. Inspection of distribution oil fuse cutouts. In addition to applicable general inspection requirements, the following items should be included:

(1) Sample insulating oil periodically and test for dielectric breakdown strength. Cutouts that experience regular load-break or fuse-interrupting duty should have their oil tested on a more frequent basis.

(2) Nonvented distribution oil fuse cutouts generally incorporate insulating materials in the fuse carriers that may be damaged dielectrically by excessive exposure to moisture or to a humid atmosphere. Keep the cutout sealed so that components and oil are protected from any contaminating exposure.

(3) Fuse elements are generally not interchangeable, and any substitution for the manufacturer's fuses may seriously affect the interrupting characteristics of the device.

(4) Examine cutouts for any evidence of oil leakage, and maintain the prescribed oil level.

(5) Check moveable bearing gasket surfaces, yoke compression, and interlocking features for satisfactory operation.

Section III-SWITCHES

8-9. Switch usage.

Switches are used to open or close circuits that may or may not be energized. If used for opening energized circuits, the switch contact construction must be capable of interrupting the current flow. Switches do not open the circuit automatically on

some predetermined current overload. This function is provided by a fuse in series with a switch.

a. Operation. Switches can be controlled manually by the lineman at the switch location, or by control signals (initiated either manually or automatically) to operate electric, hydraulic, or pneu-

matic switch-operating mechanisms at the switch location.

b. Insulation. Insulation for the voltage and current interrupting level may be provided by operating the contacts in air, oil, vacuum, or in a sulfur hexafluoride (SF₆) gas medium.

c. Load interrupting ability. Switches are classified by their ability to interrupt load.

(1) *Disconnecting switch.* This is a device used to open, close, or change the connections in a circuit or system. It has no interrupting rating and is used for isolating equipment only after the circuit has been opened by some other means. Two special types are as follows:

(a) *Grounding switch.* This is a switch used to connect a circuit or piece of equipment to ground.

(b) *Horn-gap switch.* This is a switch provided with arcing horns to aid in dispersing any arc that may occur when the switch is operated. This combination is sometimes referred to as an air-break switch. It should not be operated except to interrupt the charging current of a short length of line, or the magnetizing current of a de-energized transformer. Oil switches should always be considered as disconnect switches, unless the switch nameplate indicates a fault-closing rating suitable for the system's maximum available fault.

(2) *Interrupter switches.* Interrupter switches have specific capabilities for switching one or more of the following type of loads: 0.8 minimum lagging power factor load, parallel or loop load, transformer magnetizing load, line charging load, cable charging load, and capacitor bank load. Follow the manufacturer's instructions when operating interrupter switches.

(a) *Nonfault closing type.* This is a switch equipped with means of interrupting current, at rated voltage, not in excess of the switch's continuous rated current. Interrupter switches, which do not have a fault-closing rating, may be damaged if inadvertently closed on a short circuit. Appropriate precautions should be taken to avoid danger to the operator.

(b) *Fault closing type.* This is a switch equipped with means for interrupting current, at rated voltage, in excess of the switch's continuous rated current. Interrupter switches with fault-closing ratings are intended to provide adequate personnel protection, when closing into a short circuit, up to the asymmetrical fault-closing rating of the switch and when applied in accordance with the manufacturer's recommendation.

8-10. Operation of Switches.

Appropriate safety rules should be followed with special regard to the interrupting rating of the

switch. In regard to periodic operation, check the manufacturer's instructions to ensure that the switch hasn't frozen closed. The following general rules apply:

a. All switches. The following applies to the operating of all switches:

(1) Check visually that the blade is fully closed and latched or fully open, as intended by the operation.

(2) The operating mechanism is designed properly for the switch and use of undue force, in the nature of an extension of the operating handle, or an extra person on the operating handle or switch stick, may cause severe damage to the switch or operating mechanism. Freeing of an iced switch mechanism may be assisted by a few sharp raps on the vertical operating pipe or suddenly applied tugs on the operating handle.

(3) Operate power-operated switches periodically to ensure that their mechanisms and control features are functioning properly. If the circuit cannot be de-energized to operate a switch, the operating mechanism should be disengaged from the linkage. Check control circuits and mechanisms in the disengaged manner, unless disengagement will change the overall adjustment.

b. Disconnecting switches:

(1) Check that no load is being carried by the switch, prior to operating a disconnecting or horn-gap switch.

(2) Check to determine that operation does not remove necessary safety grounds, prior to opening a grounding switch. Check the circuit to confirm that it is not energized, prior to closing.

(3) Operate disconnecting switches rapidly to reduce arcing time and possible burning of contacts.

8-11. Switch maintenance.

No work should be done on switches until both sides of each phase are de-energized and properly grounded. In addition to the recommendations given herein, follow the specific maintenance directions of the switch manufacturer. For insulating medium other than air, treat as described in Section IV.

a. Frequency of inspection. Switches should be inspected visually at a frequency determined by local conditions such as atmospheric contamination, use of contamination control coatings, frequency of operation, or fault current exposure.

(1) *Need.* If a switch cannot be maintained on a periodic basis, its service life may be affected. When operated, it is recommended that the switch be opened and closed several times in order to clean the contacts and free the moving parts.

(2) *Visual aids.* Binoculars can facilitate spotting switches that are obviously in need of repair or maintenance because of broken insulators or other parts. Visual inspection of a wet switch, or the use of a temperature-scanning detector, may indicate hot spots which are possible sources of trouble. Directional microphones or ultrasonic detectors can be used to locate local corona sources needing removal.

b. Scheduling. A relatively small amount of maintenance is required on modern switches, so where possible, it is recommended that the schedule for such maintenance be coordinated with that of associated equipment. Schedule special inspection and maintenance whenever the switch has carried heavy short-circuit current.

c. Checking. Examination of de-energized and grounded switches should include the following items:

(1) *Operating mechanism.* Check the adjustment of the operating mechanism, operating rod, and interphase tie rods (if used) to ensure simultaneous and smooth operation of the switch blades. Mechanisms should be cleaned and lubricated only when so recommended, and then in accordance with the manufacturer's instructions. (Many modern switches are built with self-lubricating bearings.) Examine all metallic parts of an operating mechanism including operating handle connection for signs of rust, corrosion, and loose or broken connectors. Switches located outside of a fenced and locked area, and having operating handles at ground level, require locking provisions on handles for both the open and closed positions. Switches located within a fenced and locked area, are subject to local regulations for locking.

(a) Inspect all live parts for scarring, gouging, or sharp points, which could contribute to excessive radio noise and corona. Check corona balls and rings for damage which could impair their effectiveness.

(b) Power-operating mechanisms for switches are usually of the motor-driven, spring, hydraulic, or pneumatic type. Follow the manufacturer's instructions with regard to the limit switch adjustment. Check associated relay equipment for poor contacts, burned out coils, and adequacy of supply voltage. The complete electrical circuit of a motor-operated mechanism should be checked to ensure proper operation and wiring which is secure and free of insulation defects.

(c) Inspect, check, and test all safety interlocks for proper operation.

(2) *Insulators.* Examine insulators for cracks, chips, breaks, and evidence of flashover. Bad insulators should be replaced. Insulators should be cleaned to remove any contaminating materials

that may be present. Refer to chapter 3, section IV. The presence of an excessive amount of contamination should be reported to the supervisor, as the persistence of such a condition may require corrective measures.

(3) *Mounting.* Check mountings for evidence of rust and corrosion and to ensure proper alignment and securement. Ground connections must be tight.

(4) *Blades.* The blade or movable contact of the switch should be inspected for evidence of overheating, which may be indicated by discolorations. If overheating is caused by poor contact, it should be corrected when contacts are adjusted and cleaned. Switches that appear to be overheated, due to load currents in excess of rating, should be reported to the supervisor.

(5) *Blade Latch.* A blade latch is used on a hook stick operated switch to hold blade in closed position. Such a switch should be checked in the closed position, to determine whether the catch is functioning properly.

(6) *Contacts.* Contacts should be cleaned and adjusted in accordance with manufacturer's instructions. Modern switches are normally designed so that the contacts are self-cleaning, by virtue of the opening and closing action of the switch. After a switch remains in either position for a long time, it should be operated several times during a maintenance inspection. This operation will clean the contact surfaces. Operate only after getting clearance and after the circuit has been deenergized.

(a) Do not use a coarse abrasive to clean contacts. If contact pitting is minor, smooth the surface with clean crocus cloth or as the manufacturer recommends.

(b) Where arcing horns are used, ensure that they make contact, as intended, during opening and closing operations.

(c) A nonoxidizing lubricant should be used to protect the contacts against oxidation and to lubricate the blade hinge. Silicone greases are excellent for this purpose, as they are relatively unaffected by changes in temperature and are highly water resistant.

(7) *Terminals and connections.* Terminals should be checked to ensure that they are secure. Connections showing evidence of heat should be corrected as a high-resistance contact is indicated.

(8) *Interrupting elements.* Load interrupter switches are equipped with an interrupter element, designed to quench the arc that results when the switch is opened under loaded conditions. Basically, these elements are shunt devices, installed as part of the switch, through which current passes only as the switch is opened. In some designs the arc quenching medium is air, but for the higher voltage

switches the interrupter may use some other medium, such as sulfur hexafluoride gas. Interrupters should receive the same inspection and maintenance as the switches on which they are installed. Many interrupter switches are designed so that material is consumed from the walls which are exposed to the electric arc. Particular attention should be given to such parts, and they should be maintained or replaced in accordance with the manufacturer's

instructions. Interrupter contacts should be inspected for damage caused by arcing. Contacts showing evidence of excessive wear should be replaced in accordance with manufacturer's recommendations. Interrupters with sealed gas-filled chambers have pressure gages to indicate loss of pressure. Field experience indicates that interrupters using a sealed gas chamber will require recharging every 2.5 to 3 years or more often.

Section IV-CIRCUIT BREAKERS

8-12. Circuit breaker usage.

Circuit breakers are a special form of switching mechanism, which can open and close circuits under both normal and abnormal conditions. When they are electrically controlled, they can be operated locally or remotely, or by both modes. Oil, SF₆, gas, vacuum, and air are the insulating mediums used on most installations. The selection of the insulation generally relates to the voltage level being interrupted.

a. Voltage level relative to the insulating media selection.

(1) *High-voltage units.* Until recently most installed high-voltage circuit breakers were of the oil-insulated type. However, the use of SF₆, gas insulated units is increasing as SF₆ units take less space for a given voltage and are environmentally preferable.

(2) *Medium voltage units.* Newly installed medium-voltage switchgear utilizes vacuum construction which provides a considerable space saving over air-magnetic units now being phased out. In the future, SF₆ switchgear units will probably become more common.

(3) *Low-voltage units.* Only air-insulated power circuit breaker switchgear of the solid-state type is described in this manual.

b. *Safety measures.* Before initiating any maintenance inspection which requires touching a circuit breaker, check to ensure that:

- (1) The circuit breaker has been tripped (open).
- (2) The circuit breaker is disconnected from the circuit on both sides, either by opening disconnect switches or by removing the drawout portion of the circuit breaker from the switchgear dependent upon the installation.

(3) All control circuits are open and potential transformer fuses are removed.

(4) The supply to pneumatically and hydraulically operated circuit breakers is shut off.

(5) Wound springs in stored-energy mechanisms have been released.

(6) Circuit breakers and controls are properly tagged.

(7) The circuit breaker is grounded.

(8) Suitable barriers are installed between the circuit breaker and adjacent apparatus that may be energized. In crowded installations, barriers may be of rope or net, with suitable danger flags, or of temporary rigid construction using insulating material.

(9) Requirements of departmental safety publications are being observed.

8-13. Frequency of circuit breaker maintenance.

A circuit breaker is a much more complex and expensive item than the switch and fuse combination, which fulfills the same function to a lesser degree. Circuit breakers are therefore generally used for the more important circuits, where increased reliability and flexibility is required for equipment operation and prompt restoration of service.

a. *Frequency of inspection.* The frequency of inspection should be based on service and operating condition. A circuit breaker should be inspected whenever it has interrupted current at or near its rated capacity. The average frequencies given here should be reconsidered if the following conditions apply or as equipment ages.

(1) High humidity and high ambient temperature

(2) Dusty or dirty atmosphere

(3) Corrosive atmosphere

(4) Frequent switching operations

(5) Frequent fault operations

b. *Maintenance of nonmetalclad medium- and high-voltage circuit breakers.* Most manufacturers recommend complete inspections, external and internal, every 6 to 12 months for circuit breakers above 15 kilovolts. However, utility company experience has shown that considerable unnecessary expense may be involved in adhering to the manufacturer's recommendations. With proper external checks, the expense, delay, and labor of internal inspections may be avoided without sacrificing dependability. Internal conditions can be determined through oil analysis, power factor testing, and the

millivolt drop test. Partial maintenance can then be performed annually and complete maintenance every 5 years.

(1) Inspection schedule for new circuit breakers. A temporary schedule of frequent inspections is necessary after the erection of new equipment, the modification or modernization of old equipment, or the reapplication of old equipment under different conditions. The temporary schedule is required to correct internal defects, which may appear in the first year of service, and to correlate external check procedures with internal conditions as a basis for establishing a more conservative maintenance program thereafter. If a circuit breaker shows no serious defects during early internal and external inspections, and no heavy interrupting duty is imposed, the following inspection schedule is recommended.

(a) Twelve months after erection. External inspection and checks.

(b) Twelve months after the first inspection. Complete inspection and adjustment.

(c) Twelve months after previous inspection. If no problems, perform regular maintenance. If there are problems, another inspection should be performed after 12 months; then return to the maintenance schedule for existing circuit breakers.

(2) Inspection schedule for existing circuits breakers. Normally, no more than 1 year should elapse between external inspections and 5 years between internal inspections. It is advisable to make a complete internal inspection after the first severe fault interruption.

c. Medium-voltage circuit breakers in metalclad switchgear. Inspection and maintenance should be performed annually.

d. Circuit breakers in low-voltage switchgear. Inspection and maintenance should be performed every 5 years.

8-14. Maintenance of nonmetalclad switchgear circuit breakers.

Maintenance requirements include both general external and internal inspection guidelines. Also guidelines specific to the insulating medium (oil and SF₆, gas) are given.

a. General external inspection guidelines. The following items should be included in an external inspection.

(1) Visually inspect the circuit breaker and the operating mechanism. Carefully examine tripping latches, since small errors in adjustments, clearances, and roughness of the latching surfaces may cause the circuit breaker to latch improperly or increase the force necessary to trip the circuit breaker, such that the electrical tripping will not

always be successful. Too much opening spring pressure can cause excessive friction at the tripping latch and should be avoided. Electromagnetic forces, due to the flow of heavy short-circuit currents through the circuit breaker, may cause extra pressure on the tripping latch.

(2) Lubricate the bearing surfaces of the operating mechanism as recommended in the manufacturer's instruction book. Avoid excessive lubrication because oily surfaces collect dust and get stiff in cold weather, resulting in excessive friction.

(3) If possible, observe the circuit breaker operation under load.

(4) Operate the circuit breaker manually and electrically, and look for malfunctions. Determine the presence of excessive friction in the tripping mechanism and the margin of safety in the tripping function by testing the minimum voltage required to trip the circuit breaker. This can be accomplished by connecting a switch and rheostat in series with the trip-coil circuit at the circuit breaker (across the terminals to the remote control switch) and a voltmeter across the trip coil. Starting below 50 percent of rated trip-coil voltage, gradually increase the voltage until the trip-coil plunger picks up and successfully trips the circuit breaker. Make several trial tripping operations of the circuit breaker, and record the minimum tripping voltage. Most circuit breakers should trip at about 56 percent of rated trip-coil voltage. Measure the trip-coil resistance and compare it with the factory test value to disclose shorted turns. Many modern circuit breakers have trip coils which will overheat or burn out if left energized for more than a short period. An auxiliary switch is used, in series with the coil, to open the circuit as soon as the circuit breaker has opened. The auxiliary switch must be properly adjusted to successfully break the arc without damage to the contacts. Record the minimum voltage that will close the breaker and the closing coil resistance.

(5) Trip the circuit breaker by protective relay action.

(6) Check adjustments by measuring the mechanical clearances of the operating mechanism associated with each tank or pole. Appreciable variation between the clearance measured and the previous setting usually indicates mechanical trouble. Temperature, and difference of temperature, between parts of the mechanism affect the clearances. The manufacturer's recommended tolerances usually allow for these effects.

(7) Check the power factor of bushings and the circuit breaker.

(8) The measurement of the electrical resistance between external bushing terminals of each pole can indicate whether maintenance is required.

An abnormal increase in the resistance of this circuit may indicate foreign material in the contacts, loose contact support, loose jumpers, loose bushing connections, or corrosion. Any one of these may cause localized heating and deterioration. Measure resistance of the main contact circuits with a portable double bridge (Kelvin) or a "Ductor." The circuit breaker contacts should not be opened during this test, because of possible damage to the test equipment. Compare resistance values to the manufacturer's values or to values found on a similar circuit breaker. These values should not vary more than 25 percent between poles.

(9) Motion analyzers can provide graphic records of close or open initiation signals; contact closing or opening time with respect to initiation signals; contact movement and velocity; and contact bounce or rebound. Circuit breaker motion analyzers are portable devices designed to monitor the operation of power circuit breakers, as they permit mechanical coupling of the motion analyzer to the circuit breaker operating rod. The records obtained not only indicate when mechanical problems are present, but also help isolate the cause of the problems. Obtain a motion-analyzer record on a circuit breaker when it is first installed. This will provide a master record which can be filed and used for comparison with future maintenance checks. Tripping and closing voltages should be recorded on the master record, so subsequent tests can be performed under comparable conditions. Time-travel records are taken on the middle pole from the operating mechanism.

(10) Check the air system of a pneumatic mechanism for leaks.

(11) Check control wiring for loose connections.

(12) Check the settings of compressor switches, low pressure alarms, and cut-off switches.

(13) Inspect and check the operating mechanism. Lubricate all pins, bearings, and latches, using the recommended lubricant.

b. External inspection guidelines specific to the insulating medium used. Oil dielectric tests are needed for oil circuit breakers, and a moisture test should be provided for gas-insulated units.

(1) *Oil-insulated circuit breakers.* Check oil dielectric strength, power factor, acidity, and color. The dielectric strength must be maintained to prevent internal breakdown under voltage surges and to enable the interrupter to function properly. Its action depends upon changing the internal arc path from a fair conductor to a good insulator, in the short interval while the current is passing through zero. A manufacturer's instructions should state the lowest allowable dielectric strength. However, the dielectric strength should be maintained above 25

kilovolts, even though some manufacturer's instructions allow 16 kilovolts. If the oil is carbonized, filtering may remove the suspended particles, but the interrupters, bushings, and other internal parts must be wiped clean. If the dielectric strength has been lowered by moisture, check and eliminate the source of the moisture (such as fiber or wood parts); and dry the affected parts thoroughly before placing the circuit breaker in service.

(2) *Circuit breakers insulated with SF₆.* Circuit breakers having SF₆ insulation should be tested every 3 months during the first year of service, and at least every 12 months thereafter, to determine the moisture content of the SF₆ gas. Moisture content must also be tested when gas is added. Service equipment according to the manufacturer's instructions. Moisture content should be less than 50 parts per million by volume (ppm.). Do not energize a section of the gas-insulated equipment, if the SF₆ gas density is less than 50 percent of nominal or if the moisture content of the gas exceeds 1000 ppm.. Refer to chapter 15, section II in regard to the toxicity of SF₆ gas.

c. Internal inspection guidelines. When an internal inspection is required it should be made at the same time as an external inspection. The circuit breaker tanks or contact heads should be opened and the contacts and interrupting parts inspected. Follow these guidelines and the checklist furnished by the manufacturer. Such a checklist may provide forms useful for recording inspection and maintenance data.

(1) Internal difficulties are most likely to appear early in the use of a circuit breaker, which is why early internal inspections are recommended. As unsatisfactory internal conditions are corrected, and if one or two later inspections indicate satisfactory internal conditions, the frequency of internal inspections may safely be decreased.

(2) For circuit breakers equipped with pneumatic operators, drain and inspect the air tanks.

(3) Perform post maintenance diagnostic tests on circuit breakers in accordance with instructions from test equipment and circuit breaker manufacturers, and follow established maintenance procedures.

(4) Test operate the circuit breaker and record the number of operations. The tests should include all alarms (including control alarms), switches, and the manufacturer's recommendations.

d. Internal inspection guidelines specific to the insulating medium used. The insulating medium must be removed, as necessary, to examine the circuit breaker internally.

(1) *Oil-insulated circuit breakers.* Inspecting the tank includes removing the oil, ventilating the

tank, visually inspecting the interior, and wiping down the tank and interior parts.

(a) Maintenance of the integral parts (contacts, interrupter assemblies, internal current transformers, resistors, capacitors, and lift rods) includes checking, measuring, adjusting, aligning, and making repairs as needed. Lubricate all parts and components that are required to be lubricated. Replace any seals and gaskets, if necessary. Replace all desiccant materials, if applicable.

(b) Reseal the tank after inspection and maintenance.

(c) Refill the tank to the proper oil level and inspect for leaks.

(2) *Circuit breakers insulated with SF₆ gas.* Remove SF₆ gas from the circuit breaker; transfer the gas from the circuit breaker (use a gas processing unit); pull a vacuum on the circuit breaker to be certain that all of the gas has been removed; and release the vacuum on the circuit breaker with dry air or nitrogen to avoid pulling moisture into the tanks.

(a) Inspecting the tank includes opening the tank, vacuuming any residue (if present), ventilating, and wiping the inside of the tank with approved solvent.

(b) Inspect all parts for wear and damage, including the fiberglass components and seals.

(c) Install factory-recommended overhaul and sealer kits. Replace all desiccant materials, if applicable.

(d) Perform any repairs or adjustments.

(e) Seal the circuit breaker tank and pull a vacuum in accordance with manufacturer's specifications. If the vacuum holds for the specified amount of time, this indicates that no leaks are present.

(f) Refill the tank to the proper pressure.

e. *Typical internal circuit breaker problems.* Evidence of the following tendencies indicate internal problems which need to be corrected.

(1) Loosening of keys, bolts (especially fiber), cotter pins, operating rods, supports, and guides or an indication of wear or weakness.

(2) Formation and accumulation of carbon or sludge in the interrupter or on bushings.

(3) Indication that the interrupter is inclined to flash over and rupture the static shield or resistor or interrupter parts or barriers are disposed to burn or erode.

(4) Indication that bushing gaskets have leaked moisture into the circuit breaker insulating material.

(5) Cracks in any of the above parts.

f. *Influence of duty imposed.* The need for maintenance is influenced by any circuit breaker's operating duty. The influence of operating duty given below for oil circuit breakers will also apply (except for the different insulating medium) to SF₆ gas-insulated circuit breakers.

(1) *Influence of light duty.* If the circuit breaker has been energized on both sides, but the contacts are open, erosion in the form of irregular grooves (called tracking) may appear on the inner surface of the interrupter or shields, due to electrostatic charging current. This is usually aggravated by a deposit of carbon sludge, which has previously been generated by some interrupting operation. If the circuit breaker has remained closed and is carrying current, evidence of heating of the contacts may be found if the contact surfaces were not clean, have oxidized, or if the contact pressure was improper. Any shrinkage and loosening of wood or fiber parts (due to loss of absorbed moisture into the dry oil) will take place following the circuit breaker installation, independent of the circuit breaker operation. However, mechanical operation will make any loosening more evident. If possible, before inspection, open and close the circuit breaker while energized. If this is not possible, additional information may be gained by operating the deenergized circuit breaker several times, measuring the contact resistance of each pole before and after each operation.

(2) *Influence of normal duty.* The severity of duty imposed by load switching, line deenergizing, and fault interruptions depends upon the type of circuit breaker involved. In circuit breakers which employ an oil blast generated by the power arc, the interruption of low current faults or line charging current may cause more deterioration, because of low oil pressure, than the interruption of high current faults. In some designs using this basic principle of interruption, distress at low interrupting duty is minimized by multiple breaks, rapid contact travel, and turbulence of the oil caused by movement of the contact and mechanism. In designs employing a mechanically driven piston to supplement the arc-driven oil blast, the performance is more uniform. Better performance is yielded by designs which depend upon a mechanically driven oil blast for arc interruption. In this type, contact erosion may appear only with heavy interruptions. The mechanical stresses that accompany heavy interruptions are always more severe. These variations of performance among various designs must be considered when evaluating the need for maintenance and performance of a circuit breaker. Because of these variations, the practice of evaluating each fault interruption as the equivalent of 100 no-load opera-

tions is approximate, although it may be a useful guide in the absence of other information.

(3) *Influence of severe duty.* Contact erosion and damage from severe mechanical stresses may occur during large fault interruption. Reliable indication of the stress, which a circuit breaker is subjected to during fault interruptions, can be obtained by automatic oscillograph records on systems which provide this feature. Deterioration of the circuit breaker is proportional to the energy dissipated in the circuit breaker during the interruption. The energy dissipated is proportional to the current and the duration of arcing, that is, the time from the moment the contacts part to current interruption. However, oscillographs do not always record the moment that the contacts part, and it may be necessary to determine the parting from indicated relay time and the known time for circuit breaker contacts to part. When automatic oscillograph records are available, they may be as useful in guiding oil circuit breaker maintenance as in showing relay and system performance. When automatic oscillographs are not available, an approximate indication of fault duty imposed on the circuit breakers may be obtained from relay targets and accompanying system conditions. All such data should be tabulated in the circuit breaker maintenance file.

8-15. Maintenance of metalclad circuit breakers.

The insulating media covered include air and vacuum.

a. *General maintenance procedures.* The following suggestions are for use in conjunction with manufacturer's instruction books for the maintenance of drawout medium-voltage circuit breakers installed in metal-clad switchgear. Record all problems.

(1) *Basic requirements.* Drawout devices should be removed for inspection and operation. During inspection all deposits or dust will be removed with a clean lint-free cloth; a vacuum cleaner might be helpful. All smoothing of surfaces should be done with crocus cloth.

(2) *Operating history.* Record the number of operations of the circuit breaker.

(3) *Test position.* Before complete removal put the circuit breaker in the test position. Use a test coupler to operate the circuit breaker electrically. Check the performance of all controls such as protective relays, switches, motors, indicating devices, and alarms.

(4) Remove the drawout portion of the circuit breaker and perform visual inspections, operations,

measurements, tests, and final checks before inserting the drawout portion into the switchgear cubicle for re-energization as appropriate.

b. *Air-circuit breaker maintenance requirements.* Remove box barriers from the circuit breaker and clean all insulating parts including the bushings and the inside of the box barriers. The unit is now ready to be inspected, operated, and tested.

(1) *Visual inspections.* Inspect the unit to determine its operating condition. Perform any repairs in accordance with the manufacturer's instructions.

(a) Check the bushing primary disconnect stubs and finger cluster. Bushing insulation should be clean, dry, smooth, hard, and unmarred.

(b) Check insulation and outside of arc chutes for holes or breaks; small cracks are normal. If ceramics or fins are broken replace arc chutes. The throat area of arc chutes may need to be cleared of contamination with crocus cloth.

(c) Check arcing and primary contacts for uneven wear, or impairment from burns and pitting. Correction of damage by smoothing or resilvering may be necessary. Replace badly damaged contacts. Follow the same procedure for primary disconnect stubs and other current-carrying parts. Grease contacts with an approved grease.

(d) The tightness of all connections is of paramount importance. Check and tighten or secure, as necessary, any loose nuts, bolts, retaining rings, and mechanical linkages which are a part of the circuit breaker and its operating mechanism. Ensure that all electrical wiring connections are secure.

(e) Check all bearings, cams, rollers, latches, and buffer blocks for wear. Teflon-coated sleeve bearings do not require lubrication. All other sleeve bearings, rollers, and needle bearings should be lubricated with SAE 20 or 30 machine oil. Lubrication is not required on ground surfaces having a dark molybdenum disulfide coating. Lubricate all other ground surfaces such as latches, rollers, or props with an approved grease.

(f) Check actuator relays, the charging motor, and secondary disconnects for damage, evidence of overheating, or insulation breakdown.

(g) Check contacts of control relays for wear and clean as necessary.

(h) Check for possible damage to wiring and replace any wiring with worn insulation.

(i) Check for damage to magnetic blow-out coils if they are used.

(2) *Operations and measurements.* After correcting any deficiencies revealed by the visual inspection, perform these circuit breaker operations and measurements.

(a) If the primary contact gap required adjustment, operate the circuit breaker several times to verify correct performance.

(b) Check the operation and the clearance of the trip armature travel, and release the latch in accordance with the appropriate instruction book. Replace any worn or damaged parts disclosed by this operation.

(c) On stored-energy circuit breakers, operate the circuit breaker slowly. By using the spring blocking device, check for binding or friction, and correct if necessary. Make sure contacts can be opened or closed fully.

(d) Reinstall box barriers and measure insulation resistance of each bushing terminal to ground and phase to phase. Record resistance readings and also temperature and humidity.

(3) *Tests.* Perform tests every 1 to 3 years dependent upon the severity of duty encountered by the circuit breaker.

(a) Perform a hi-pot test on the circuit breaker bushings.

(b) Check the closed circuit breaker contact resistance.

(c) Perform a power factor test.

(d) Perform a corona test.

(4) *Final checks.*

(a) Using the coupler, test operate the circuit breaker both electrically and manually. Check all interlocks.

(b) Insert and operate the circuit breaker in the switchgear cubicle. Watch for proper operation of the positive interlock trip-free mechanism. The circuit breaker should trip whenever it has not been fully inserted, or whenever it is in the test position.

(c) Remove the circuit breaker from the switchgear cubicle and check the primary disconnect wipe. Refer to the appropriate instruction book.

(d) Insert the circuit breaker into the switchgear cubicle, ready for energization.

c. Vacuum circuit breaker procedures. Direct inspection of the primary contacts is not possible, because they are enclosed in vacuum containers. The operating mechanisms are similar to the air circuit breakers, and may be maintained in the same manner. It is not recommended that a vacuum circuit breaker be operated more than 2,000 times without an inspection.

(1) *Specific checks applying to vacuum circuit breakers.* Checking for contact erosion and vacuum condition is made with the circuit breaker removed from its switchgear cubicle.

(a) Close the circuit breaker and measure the spring plate overtravel. Consult the manufac-

turer's instruction book for allowable overtravel. If the specified overtravel is exceeded, the vacuum interrupter must be replaced because of excessive contact erosion.

(b) Perform a high-potential test to check the condition of the vacuum. Consult the manufacturer's instruction book for test value, or use 60 percent of the final factory test value.

(2) *Other requirements.* Follow appropriate requirements given for air circuit breakers.

d. Metalclad switchgear. Inspect enclosure housing, buses, and other switchgear members every time that circuit breakers are inspected. Supplement the following with the manufacturer's recommendations:

(1) *Enclosure housing.* The enclosure housing's function is to eliminate personnel exposure to line parts and to protect equipment from environmental deterioration.

(a) Establish a program to regularly lubricate hinges, latches, and locks and maintain enclosure finishes.

(b) Outdoor assemblies require elimination of moisture. Check space heaters and fans and their thermostats for proper functioning. Ventilators must be clear of obstructions and air filters require systematic cleaning. Check for roof or wall leaks and for floor openings which may require sealing.

(2) *Buses.* De-energize buses and ground in accordance with safety requirements. Inspection, cleaning, tightening, and testing for buses are as necessary as for circuit breakers.

(a) Inspect the surface of all insulating members for damage before any cleaning or dusting, as well as after cleaning. Damage caused by electrical distress will usually be evident on the insulating surface as corona markings or tracking parts.

(b) Inspect with special care the areas most susceptible to tracking, corona, and thermal heating. These areas include splices and junction points, boundaries between adjoining insulators, between an insulating member and a grounded metal surface, or bridging paths across insulating surface. Check also for electrical distress that can occur on hidden surfaces, such as adjacent edges between upper and lower members of split bus supports or on sharp edges in the switchgear that are not insulated.

(c) Remove dust and dirt on both phase and ground buses by wiping with a dry, clean cloth or by vacuuming.

(d) Check tightness of accessible bolted bus joints by the calibrated wrench method. Refer to manufacturer recommendations for proper torque

values. Also check alignment and contacts of primary disconnecting devices for abnormal wear or damage. Check for sulfide deposits and use a solvent, such as alcohol, for removal of these deposits.

(e) After cleaning and adjusting, run insulation resistance tests to measure resistance to ground and compare with previous readings for any sign of weakening of the insulation system. Comparisons should be made using a common temperature and humidity base.

(3) *Miscellaneous checks.* Check supporting devices such as protective relays and controls as covered in chapter 11 and as follows:

(a) Test key interlock systems by a key exchange made with devices operating in an off-normal position to ensure that they have not been bypassed. A closure attempt is required on locked-open devices and an opening attempt is required on locked-closed devices.

(b) Finally, compare equipment nameplate information with latest one-line diagram and report discrepancies.

8-16. Maintenance of low-voltage power circuit breakers.

The following guidelines are provided for maintenance of low-voltage circuit breakers. Also follow the manufacturer's detailed instruction.

a. *Maintenance.* Maintenance is given for drawout circuit breakers. Modify instructions, as required, if circuit breakers are of the fixed type.

(1) Initially check that the circuit breaker is in the test position, prior to withdrawing it from its enclosure.

(2) Clean insulating parts, including bushings.

(3) Check the alignment and condition of the movable and stationary contacts, and adjust according to the manufacturer's instruction book.

(4) Check arc chutes and replace any damaged parts.

(5) Inspect the circuit breaker operating mechanism for loose hardware and missing or broken cotter pins. Examine the cam, latch, and roller surfaces for damage or wear.

(6) Clean and lubricate the operating mechanism with a light machine oil (SAE-20 or SAE-30) for pins and bearings. A nonhardening grease should be used for the wearing surfaces of cams, rollers, and other operating parts.

(7) Set the circuit breaker's operating mechanism adjustment, as described in the manufacturer's instruction book. Excessive wear and the need for a complete overhaul is usually indicated when these adjustments cannot be made within the specified tolerances.

(8) Replace contacts, if badly worn or burned, and check the control device for freedom of operation.

(9) Inspect wiring connections for tightness.

b. *Switchgear.* Follow the appropriate recommendation for medium-voltage switchgear.

8-17. Repair of circuit breakers.

Table 8-1 is a troubleshooting chart for the oil portion of medium- and high-voltage oil-insulated circuit breakers. Table 8-2 is a troubleshooting chart for medium- and low-voltage power circuit breakers.

Table 8-1. Troubleshooting chart for oil problems

Trouble	Cause	Remedy
Insufficient oil (in oil-circuit-breaker tanks).	Leakage of oil. Oil throw during operation.	Locate point of leakage and repair. Tighten up joints in oil lines. Fill oil tanks to proper oil level.
Dirty oil (in oil-circuit-breaker tanks).	Carbonization from many operations.	Drain poor oil, and filter or replace with new oil. Clean inside of tank and all internal parts of breaker.
Moisture present in oil.	(1) Condensation of moist atmosphere. (2) Entrance of water from rain or other source.	(1) Drain and filter oil or put in new oil. (2) Repair source of water entrance.
Sludging of oil.	Overheating.	Filter or put in new oil. Remove source of overheating.
Gaskets leaking.	Improper installation of gaskets at a previous inspection or repair. Oil saturation.	Put in new gaskets, treated in accordance with circuit breaker instruction book.
Insulation failure.	Absorption of moisture and accumulation of dirt, grime, carbon and the like on bushing and insulating parts.	Thoroughly clean all insulated parts. Bake or dry out water-soaked parts (or treat in accordance with directions in the circuit breaker instruction book).

Table 8-2. Troubleshooting chart for power circuit breakers

Trouble	Cause	Remedy
Overheating	<p>Poor condition of contacts:</p> <p>(1) Out of proper alignment and adjustment.</p> <p>(2) Burned and pitted because of lack of attention after many heavy operations, or too frequent operation.</p> <p>(3) Circuit breaker kept closed (or open) for too long a period (copper contacts).</p> <p>(4) Overloading (continuous or prolonged current in excess of circuit breaker rating).</p> <p>(5) Transmission of heat to the circuit breakers from overheated or inadequate cables or connection bars.</p> <p>(6) Loose connections or terminal connectors.</p> <p>(7) Ambient temperature is too high.</p>	<p>(1) Contacts should be lined up and adjusted properly.</p> <p>(2) Burned and pitted contacts should be dressed up, if practical, or replaced with new parts. (High-pressure butt-type contacts usually do not require dressing. Silver-to-silver contacts should be dressed very carefully and only when actually required.)</p> <p>(3) Operate circuit breaker more frequently to wipe contacts clean. It may be advisable to consider the installation of new silver-to-silver contacts. The nearest manufacturer's should be consulted.</p> <p>(4) If the circuit breaker is overheating because of excess current, one of two remedies can be followed:</p> <p>(a) Replace with circuit breaker having an adequate rating for the present or future load.</p> <p>(b) Arrange circuits to remove the excess load.</p> <p>(5) If the bars or cables overheat because of current in excess of their capacity, this can be remedied by increasing the carrying capacity (that is, increasing the size or number of conductors) or by removing the excess current from the circuit.</p> <p>(6) Tighten.</p> <p>(7) Relocate in a cooler place, or arrange some means of cooling.</p>
Failure to trip	<p>(1) Mechanism binding or sticking. Caused by lack of lubrication or mechanism out of adjustment.</p> <p>(2) Failure of latching device.</p> <p>(3) Damaged trip coil.</p> <p>(4) Blown fuse in control circuit (where trip coils are potential type).</p> <p>(5) Faulty connections (loose or broken wire) in trip circuit.</p> <p>(6) Damaged or dirty contacts on tripping device.</p>	<p>(1) Lubricate mechanism. Adjust all mechanical devices, such as toggles, stops, buffers, and opening springs, according to the instruction book.</p> <p>(2) Examine the latch surface. If worn or corroded, it should be replaced. Check latch wipe, and adjust according to the instruction book.</p> <p>(3) Replace damaged coil.</p> <p>(4) Replace blown fuse.</p> <p>(5) Repair faulty wiring. See that all binding screws are tight.</p> <p>(6) Dress or replace damaged contacts or clean dirty contacts.</p>
Failure to close or to latch closed	<p>(1) Mechanism binding or sticking because of lack of lubrication or improper adjustment of the circuit breaker mechanism.</p> <p>(2) Burnout of operating (closing) coil (of electrically operated breakers) caused by operator holding the control switch closed too long.</p> <p>(3) Closing relay sticking.</p>	<p>(1) Lubricate mechanism. Adjust all mechanical devices, such as toggles, stops, buffers, and opening springs, to specifications in the circuit breaker instruction book.</p> <p>(2) Replace damaged coil and teach the users the proper method of operation. A better remedy would be to change the connections to include an auxiliary switch, which automatically cuts off the closing coil as soon as the circuit breaker closes.</p> <p>(3) Check or adjust the closing relay.</p>

Table 8-2. Troubleshooting chart for power circuit breakers (continued)

Trouble	Cause	Remedy
Failure to close or to latch closed (con't)	(4) Cutoff switch operating too soon.	(4) Adjust operation of the cutoff switch to delay cutoff so as to allow the circuit breaker to close fully.
	(5) Cutoff switch operating too late, causing the circuit breaker to bounce open.	(5) Readjust to reduce power at the end of the stroke, and eliminate bounce.
	(6) Insufficient control voltage (of an electrically operated circuit breaker) caused by:	(6) Provide the following:
	(a) Too much drop in leads	(a) Install larger wires; improve contacts at connections.
	(b) On ac control-poor regulation.	(b) Install larger control transformer. Check rectifier, and be sure it is delivering adequate dc voltage from adequate ac supply.
	(c) On dc control-battery not fully charged or in poor condition.	(c) Give battery a sustaining charge, or repair according to instructions by the battery manufacturer.
	(7) Blown fuse in control circuit, faulty connection or broken wire in control circuit, damaged or dirty contacts on control switch (electrically operated circuit breaker)	(7) Replace blown fuse; repair faulty connection or broken wire; dress or replace damaged contacts or clean dirty contacts in control switch.

Section V-MISCELLANEOUS DEVICES

8-18. Circuit switchers.

Circuit switchers employ SF, puffer-type interrupters for switching and protection of transformers, lines, cables, and capacitor banks, and have fault-interrupting ratings suitable for use in protecting medium- to heavily-loaded transformers. They are used for voltage levels of 34.5 kv and up as an intermediate protective step between less costly fused switch combinations and more expensive circuit breakers. Models are available with and without integral disconnect switches. Operation of circuit switchers is initiated by manually operating the switch; by remote supervisory control equipment; or by relays that automatically sense predetermined system or equipment conditions or electrical failures (faults). Maintenance should use the appropriate requirements for switches and SF, interrupters.

8-19. Automatic circuit reclosers.

Automatic circuit reclosers are self-contained devices for interrupting and automatically reclosing an alternating current circuit during the fault conditions. Reclosers are provided with a predetermined sequence of opening and reclosing, followed by resetting, hold closed, or lockout. They can be used on single-phase or three-phase circuits. Some circuit breakers are provided with reclosing relays and other devices, which act in the same manner as automatic circuit reclosers. Reclosers may be insulated with oil or operate with vacuum or SF, gas bottles, similar to circuit breakers. They may be magnetically or electronically operated:

a. Operation. Keep a record of counter readings, settings, and sequence of operation, in addition to normal maintenance and test data.

(1) *Reclosing after operation to lockout.* First make a complete visual inspection of the recloser for evidence of external damage, such as broken or cracked bushings, or thrown oil. Only after inspection indicates that everything is in order and there is positive evidence that the fault has been removed may the unit be closed again.

(2) *Cold-load pickup.* Excessive currents can occur on circuit re-energization and cause operation of the recloser to lockout. Such currents should be eliminated by following specific operating instructions provided dependent upon the cause of the excessive current.

(a) Inrush currents associated with motor starting, transformers, and the like can cause excessive currents. The duration of this component of cold-load pickup is quite short, a matter of several cycles.

(b) An increase in the load values relative to the previous load values due to loss of diversity of cycling loads (electric heating, air conditioners) can cause excessive currents. The ratio of the post interruption load to pre-interruption load varies with the length of interruption, but can be as high as two. This effect may cause excessive currents to persist for tens of minutes.

(c) Where cold loads cannot be picked up, circuits may be sectionalized to disconnect part of the load, or reclosers may be bypassed temporarily. Nonseries coil reclosers may have special control provisions to allow for the inrush component of cold-

load pickup. Never hold the operating lever of series coil reclosers in a closed position in an attempt to pick up cold load.

b. Frequency of maintenance. Provide maintenance after a number of operations, or after a time interval, in accordance with the manufacturer's recommendations, local operating experience, or a combination of these.

(1) *Maintenance based on elapsed time.* Operating service and local conditions influence maintenance frequencies. Inspect initially in accordance with the manufacturer's recommendations. Humidity and temperature can affect the frequency of necessary maintenance. Therefore, a study of maintenance records extending over several years can be helpful in determining proper maintenance schedules on large facilities.

(2) *Maintenance based on number of operations.* Reclosers may be maintained after a certain number of operations, determined from the recloser operation counter readings. A procedure for evaluating useful life of an oil-filled recloser, based on standard duty, is given in ANSI C37.61/IEEE 321, appendix B but is not recommended for use by maintenance personnel.

(3) *Maintenance based on elapsed time and number of operations.* The use of time interval alone does not take into account the frequency and severity of the recloser operations. On the other hand, use of the number of operations alone ignores elapsed time, during which the insulating medium may have deteriorated.

(4) *Suggested frequency.* An industry-suggested method of combining the elapsed time and operation factors is as follows: Maintenance, internal inspection, and testing of reclosers should be performed at 100 operations or every 3 years, whichever occurs first if no better basis can be established.

c. Field inspection. After installation, a recloser should be carefully inspected at the established interval. An inspection should include examining the bushings for cracks, as well as other items recommended by the manufacturer. Inspect oil-insulated unit tanks for leakage. Record the counter reading. Bypass and isolate the recloser by suitable means, if possible, and perform an operating test. Manually operate the recloser several times to the lockout position, by means of a switch stick or other control. Operating tests can disclose possible troubles and do prevent the accumulation of high-resistance oxides on contact surfaces.

d. Maintenance. Give the following items particular attention:

(1) *Oil-insulated unites.* Never assume that new oil is free of moisture. It should be tested for

dielectric strength before using, with breakdown across a standard 0.1-inch (2.54-millimeter) gap occurring at not less than 26 kilovolts root mean square (rms), the minimum acceptable dielectric strength for new oil. Breakdown at a lower test voltage usually indicates excessive moisture in the oil. Remove any moisture by filtering before the oil is used. Always test the oil before putting back in service a recloser which has been temporarily removed for repair. Replace with clean dry oil if the dielectric strength of the oil is less than 22 kilovolts rms.

(2) *Vacuum interrupting units.* Leaks caused by excessive mechanical strain, insufficiently degassed contact materials, or other causes may decrease the unit's dielectric strength. The dielectric strength of the vacuum gap can be tested with a 60-hertz high-potential test at the manufacturer's recommended voltage.

(a) Adjust vacuum contacts for proper contact opening travel, contact closing overtravel, and contact closing force, according to the manufacturer's recommended procedure.

(b) X-radiation may be produced when vacuum interrupters are energized above maximum rated voltage. Follow the manufacturer's required precautions.

(3) *Units insulated with SF₆ gas.* Follow the manufacturer's recommendations as to the insulating medium treatment.

(4) *Tests.* Test in accordance with the limits set by the manufacturer and in accordance with ANSI/IEEE C37.60.

(a) *Insulation.* Aging, moisture, and the sludge deposits can cause insulation on fiber parts and wiring to deteriorate. Test insulation by a 60-hertz high-potential test, by power factor measurement, or by dc insulation tests.

(b) *Minimum tripping current.* Make a minimum tripping current test to determine that the recloser trips at the proper current value.

(c) *Time-current characteristics.* Make a time-current characteristic test in accordance with the manufacturer's maintenance manuals and plot to compare with the manufacturer's values. Permissible tolerance from rated characteristics are plus or minus 10 percent of time or current, whichever is greater.

(d) *Lockout.* Check new or reconditioned reclosers by operating them through their sequence to lockout. The procedure will vary dependent upon the make and type of recloser.

(e) *Reset.* Check the resetting time of a recloser during the lockout test.